STALLING of TAPERED WINGS

Triangular Plan Form the Worst : "Washout" No Cure : Partial Flap Makes Matters Worse : Advantages of Wing-tip Slots in Conjunction With Partial Flaps

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1.—*Lift Distribution and Induced Velocity*

THE interesting paper by Mr. P. P. Nazir published in "The Aircraft Engineer" Monthly Technical Supplement to *Flight* of November 28th, induces me to present some results in regard to the phenomenon of stalling of tapered wings which were obtained during the last few years by the aerodynamic section of Handley Page, Limited.

The fact that a tapered wing does not stall first at the centre but at the tips and that stalling creeps inwards from there towards the centre, illustrated by Mr. Nazir's tests, is by no means new to those who have devoted their attention to the aerodynamic characteristics of tapered wings; in fact it follows immediately from the application of the Lanchester-Prandtl theory.

In order to make this point quite clear, I may be permitted to repeat a few well-known general facts on the connection between plan form, lift distribution, induced velocity and effective angle of incidence. Any aerofoil which produces lift also produces an induced velocity w, which generally varies across the span according to the distribution of lift. If we call α_g the geometric angle of incidence of any aerofoil element, and if w represents the value of induced velocity at this point, then the effective angle of incidence α_e of this aerofoil element will be:

$$\alpha_e = \alpha_g - (w/V) \quad \ldots \quad \ldots \quad (1)$$

Lift and induced velocity at any point (y_1) of the span are according to the Prandtl theory connected by the well-known function:

$$w(y_1) = \frac{V}{4\pi} \int_{-s}^{+s} \frac{\frac{d(K_L \, . \, c)}{dy} \, . \, dy}{y_1 - y} \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

which is really the nucleus of the aerofoil theory.

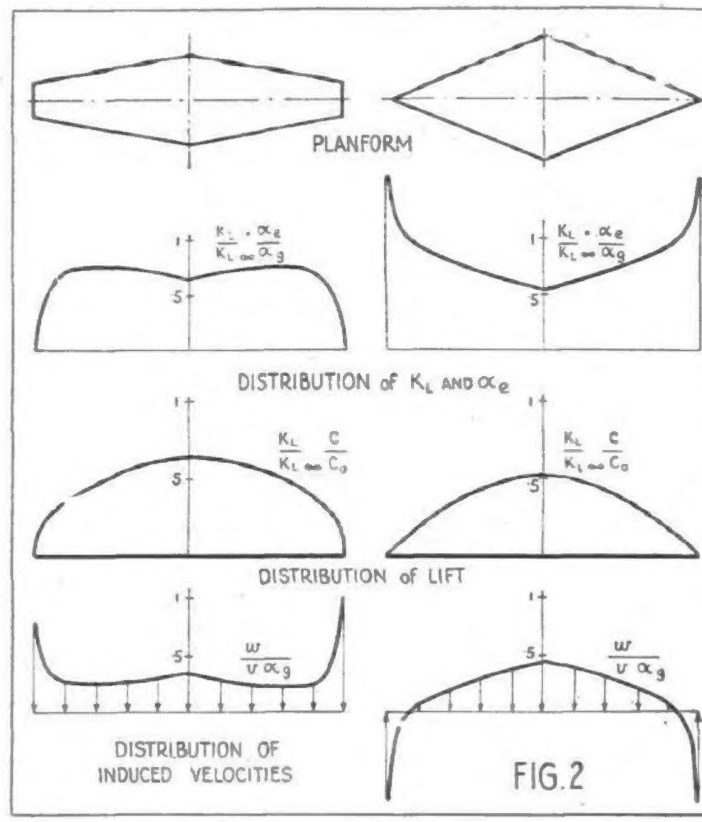

FIG. 2

In order to find the lift distribution for a given aerofoil, one can proceed as follows: One assumes in first approximation a plausible distribution of lift and calculates the downwash velocities at various points of the span according to (2).

Having found the downwash velocity the effective angle at each point of the span is known, and taking into account the lift curve of the section at this point one can determine the lift produced: $K_L = \frac{dK_L}{d\alpha} \alpha_e$.. In order to satisfy the Prandtl theory and in order to make the assumed lift distribution into the actual one, the lift thus obtained should check up with the assumed lift. This is, of course, usually not the case, and therefore a second approximation has to be made and so on until the original lift and the check lift agree.

All graphical methods, for example the methods developed by Fage,[1] Jurieff,[2] Tani,[3] etc., are based on this principle. Alternatively the lift distribution can be calculated analytically by means of a Fourier Series according to Glauert[4], or by the method of Lotz[5] which is more accurate and less cumbersome than the Glauert method. The Lotz method has been introduced in this country in a very instructive article published in the *Journal of the Royal Aeronautical Society* of May, 1934, by Shenstone.[6]

Figs. 1 and 2 contain the main calculated aerodynamic characteristics for four typical aerofoil plan forms, namely: an ellipse, a rectangle, a trapezium and a straight taper with pointed tips. From the point of view of stalling, the distribution of effective angle of incidence across the span is of particular interest. According to this, an elliptical wing stalls simultaneously over the whole span. A rect-

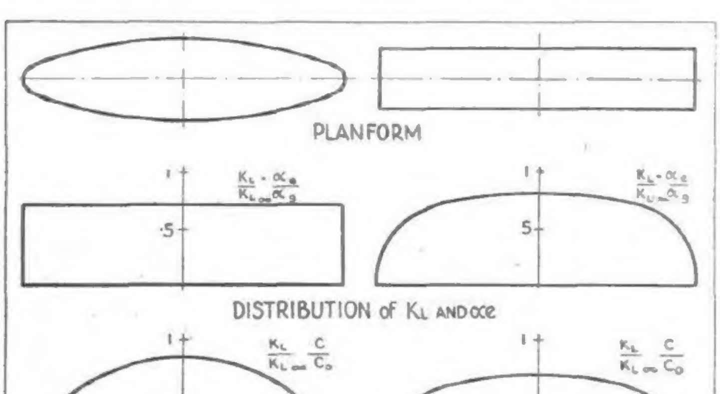

FIG. 1